CS 357 – Numerical Methods 1

Prof. Mariana Silva

Meeting Mariana

Teaching Associate Professor
Education Innovation Fellow

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Research Area: Computers and Education

- Started teaching at UIUC Sp 2012
- Taught 10 different courses
- Teaching CS 357 since Sp 2018

My research interests

- Fostering collaborations and group work in the classroom

- Exploration of technological innovations for large-scale teaching
  - Drawing tools in PrairieLearn
  - Incorporate Jupyter notebooks in PrairieLearn workspaces
  - Integrate collaborative learning features in PrairieLearn
  - Developed web-tool to build teams
  - Training and mentoring for innovation and course design

- My most recent professional adventures
  - Co-founded PrairieLearn Inc in 2021
  - Received NSF/SBIR grant in August 2023

PrairieLearn

Meet Course Staff

https://courses.engr.illinois.edu/cs357

CampusWire

- All communication will happen via CampusWire. NO EMAILS!
- Check it daily!
- Important course announcements will be pinned.

Other important announcements

- Eating is NOT allowed in classroom. You must eat your lunch before or after class.
- Course Survey and Consent Form

Office Hours

https://courses.engr.illinois.edu/cs357/pages/contact.html

- Office hours start next week (in-person and via Zoom)

Course Website - Syllabus

https://courses.engr.illinois.edu/cs357/pages/syllabus.html

PrairieLearn Content

- Lecture
- Workspaces
- Group Activity
- Homework
- Machine Problem
- Practice Quiz

Quiz Schedule

If you are supposed to take the quiz at CBTF

Exams available for reservations

Action	Exam	First date	Last date
Make a reservation	CS 357 (Sp23): Quiz 1	2023-01-30 00:01:00 (CST)	2023-02-01 23:59:00 (CST)

If you are supposed to take the BYOD quiz at CIF 3031

Exam reservations

Exam	Date	Duration	Type	Location	Accommodations
CS 357 (Fa23): Quiz 1	2023-09-07 12:30:00 (CDT)	50 min	In-person	CIF 3031	—

PrairieTest will be updated this weekend. On Monday, you should be able to either:

- See your pre-assigned registration for BYOD
- Be able to register for your CBTF quiz

First week of classes

BOTH **Tuesday and Thursday**:

- hybrid class - online and in-person synchronously
- Attendance not required, but strongly encouraged!
- Recording will be available at later time
- Mock Group Activity on Thursday. Great opportunity to meet people.

Starting from week 2

Tuesday:

- Group activity
- Attendance required only for students in section N
- Section M students should still consider in-person support/interactions

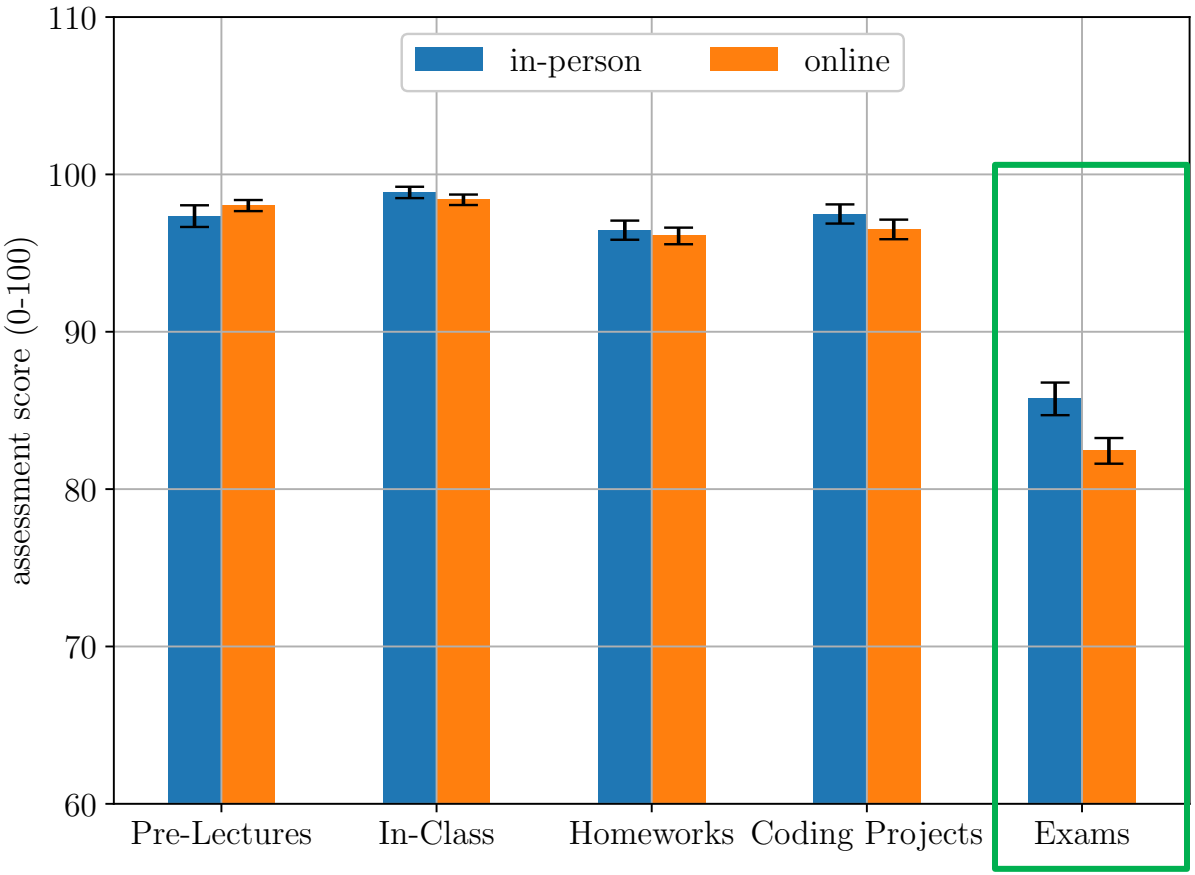
Thursday:

- Optional Study Hours
- No Zoom option
- Not recorded
- All students that want to get this additional help should go to CIF

What do we know about online vs in-person sections in CS 357?

In-person and Online students have similar performance on all “learning” assignments

What do we know about online vs in-person sections in CS 357?



In-person students have ON AVERAGE a small (2.4%) score advantage on quizzes when compared to **online** students

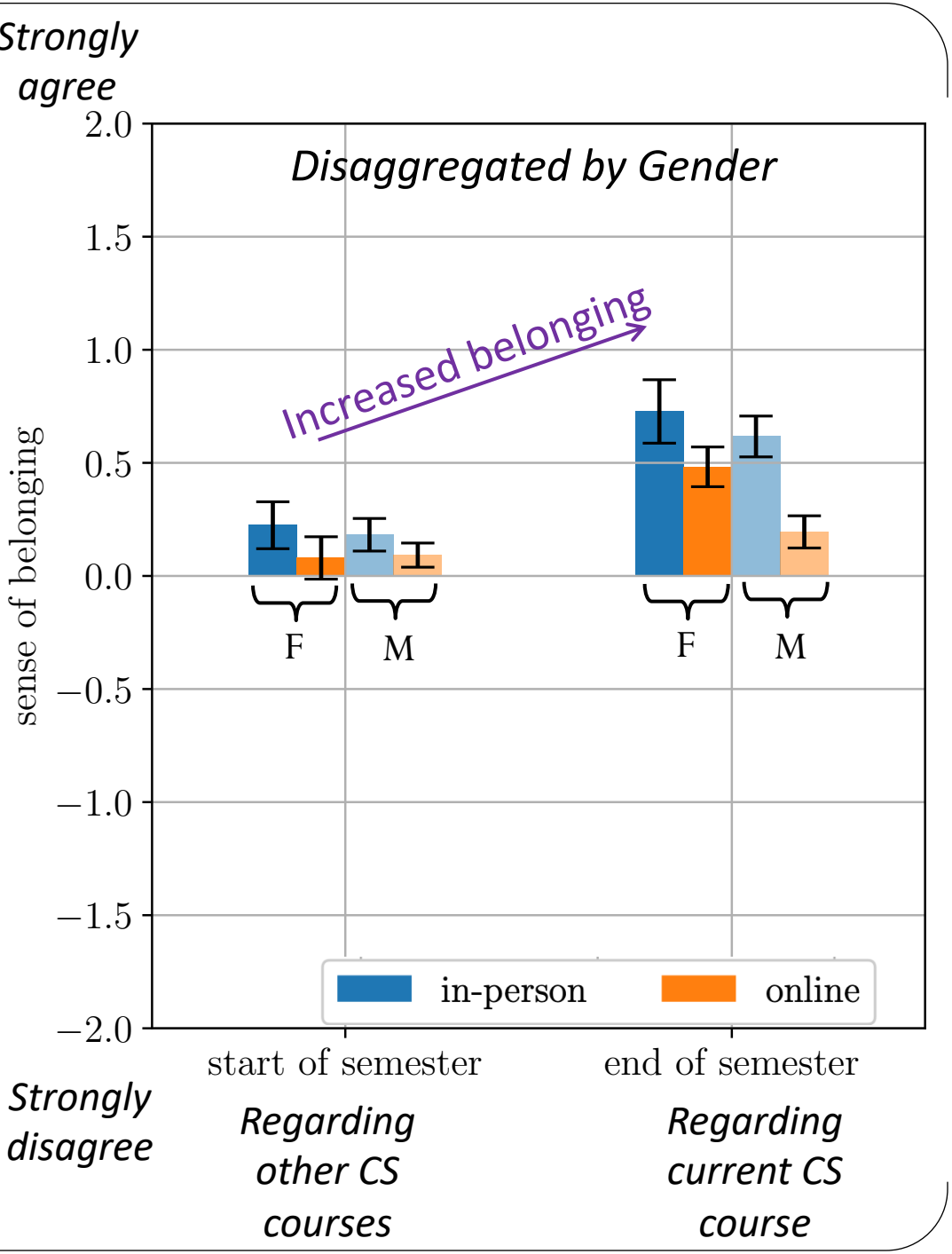
Sense of Belonging

Survey questions regarding perceived comfort, support, and isolation

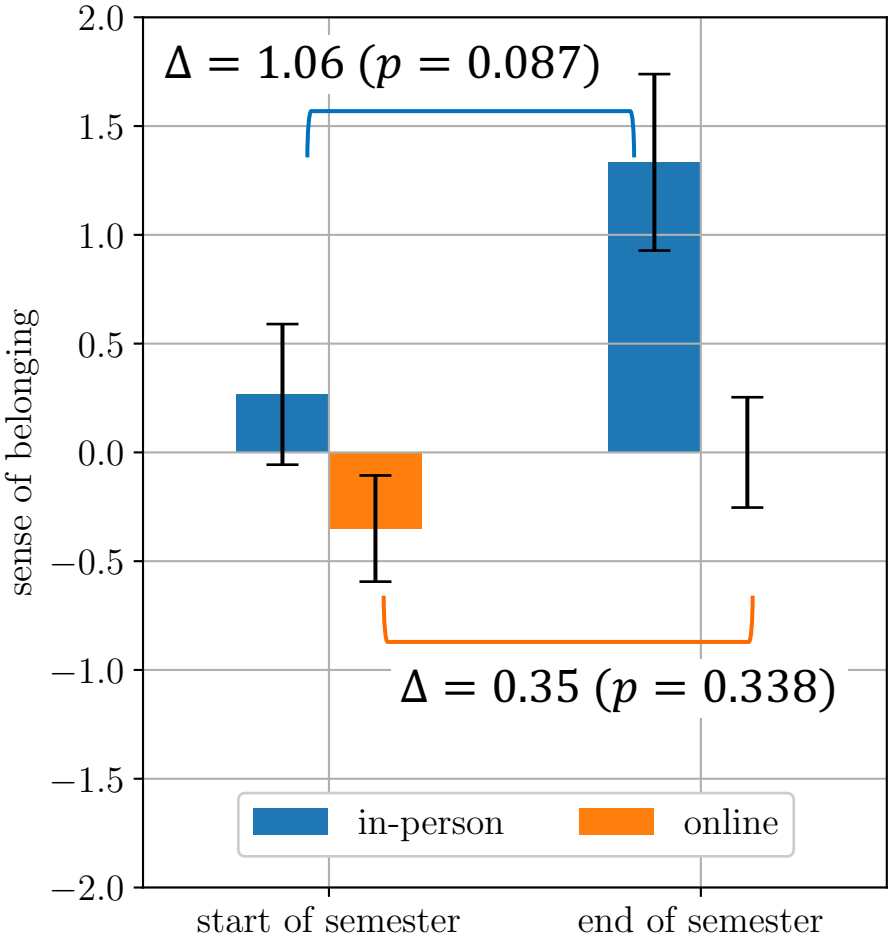
Increased SoB over the semester

In-person students report **higher increase in SoB** when compared to **online** students

Online section: not significant increase in SoB for men; significant increase in SoB for women



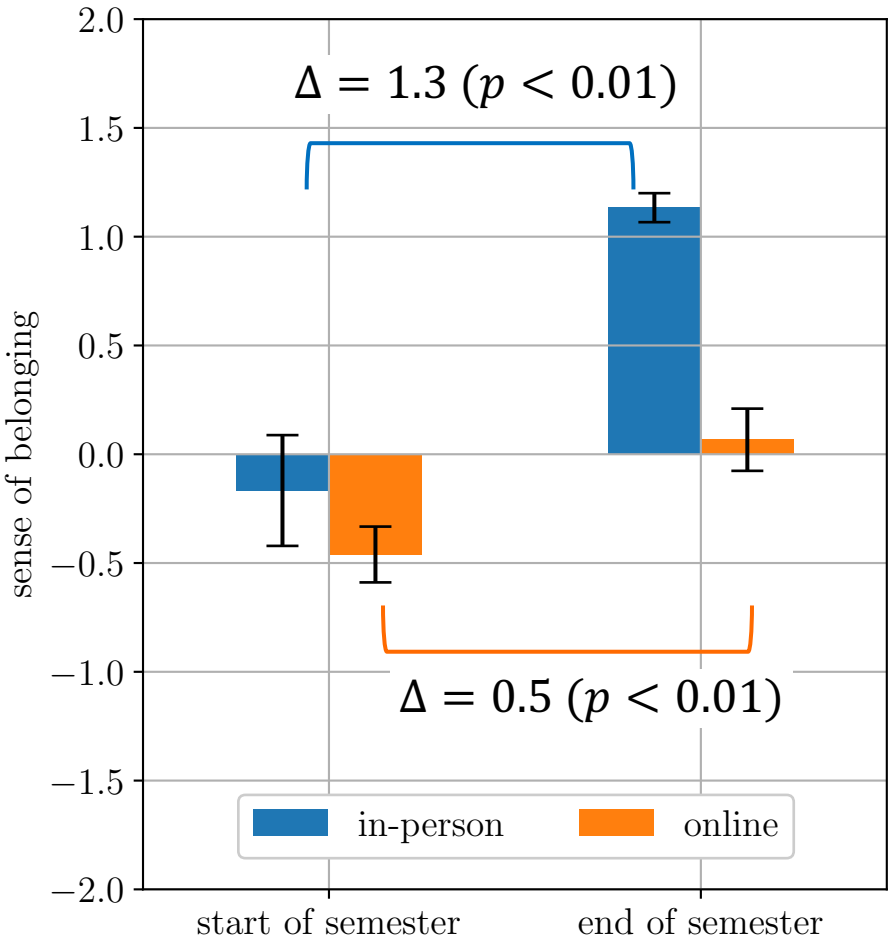
URM only



Regarding other CS courses

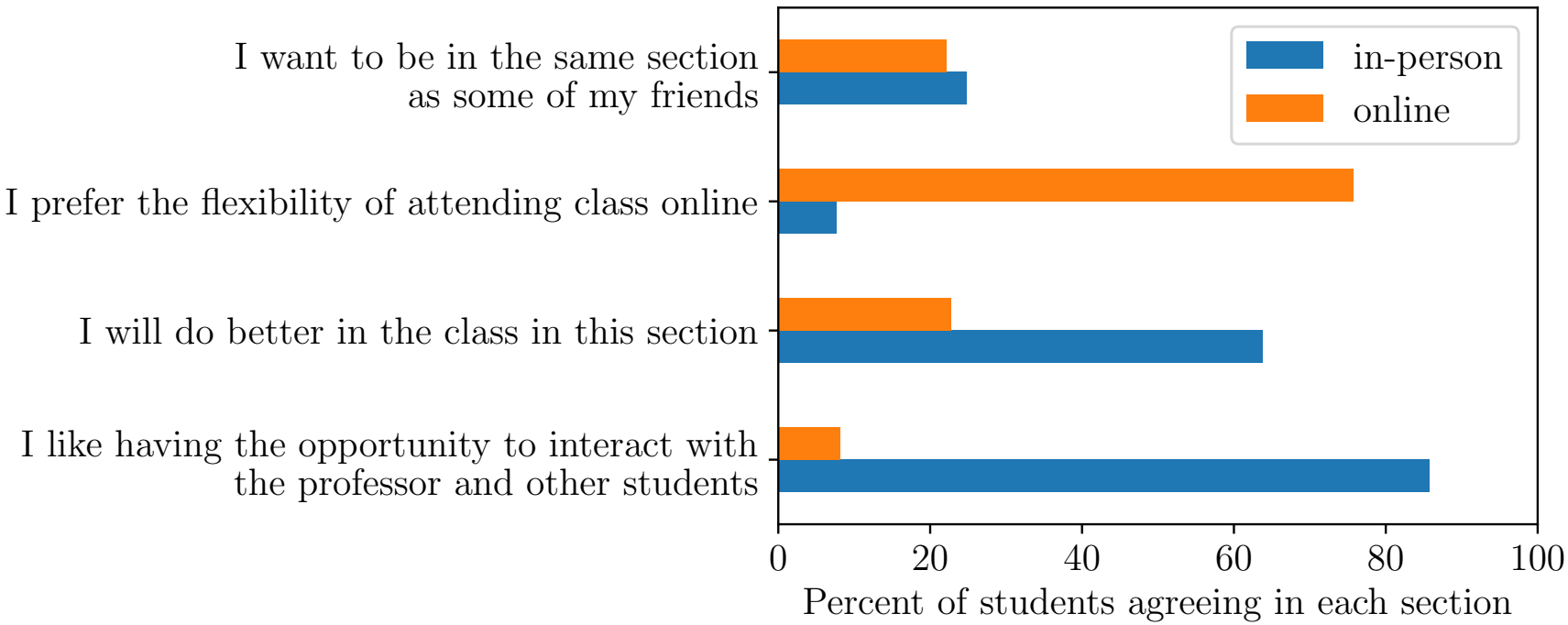
Regarding current CS course

First-Generation only



Regarding other CS courses

Regarding current CS course



Students select the section that best fit their preferences

GA support for section M students

1. **Grainger Library (in-person)**
   - Two TAs will be at the room 404
   - Student groups should find tables/seats outside 404: main study area on the 4th floor or any other location at Grainger
2. **Siebel Basement (in-person)**
   - Two TAs will be at the Tutoring Center
   - Student groups should find tables/seats at the tutoring center
3. **Zoom (online)**
   - Four TAs will be connected to Zoom
   - Use Queue to request help

Introduction and “Big Idea”

What are…

Numerical Methods ?

Numbers in a computer
(and how computer understands these numbers)

- Mathematical model
  - "algorithms" derived from math ideas to solve equations numerically
- Complexity of the problem
  - Slow vs fast
- Accuracy
  - Accurate vs inaccurate

Method = Math + Complexity + Accuracy

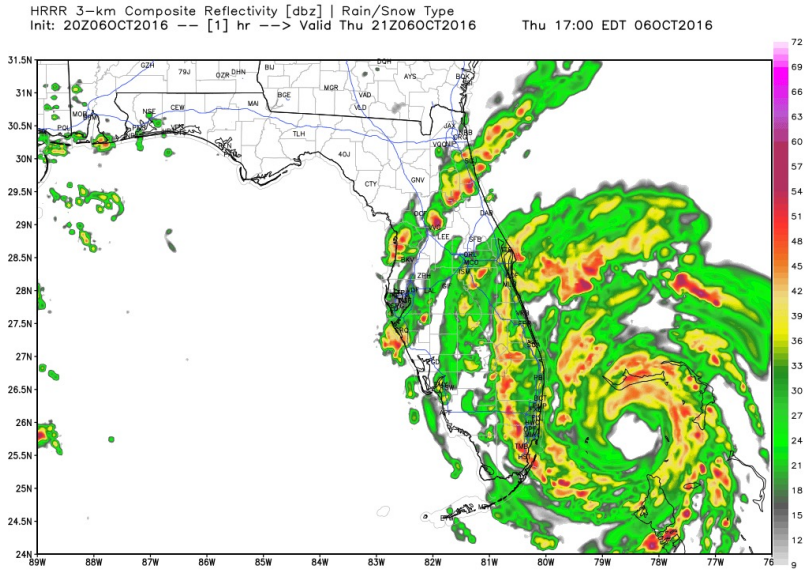
Why is this course important?

1. Understanding and reconstruction of known problems
   - Natural disasters
   - Catastrophic failures

2. Prediction of unknown situations
   - Weather conditions
   - Behavior of new materials

3. Optimization of existing problems
   - Image recognition
   - Reduce fabrication costs

Explosion of Ariane 5 in 1996



Goals for this course

- Understand how numbers are represented in the computer.
- When developing code, you will likely run into numerical errors. What are the sources of these errors?
- How can you avoid numerical errors?
- How can you choose a suitable algorithm for a given application?
- Use existing libraries to solve real applications.

(Numerical) **Method** = **Math** + Complexity + Accuracy

Mathematical model:

What equations can we use to represent our problem?

Accuracy:

Are we getting accurate results?
Why is the method not giving me the correct solution?

Complexity:

How long does it take to solve this problem?
Is it cost-effective?

Your entire CS 357 semester in a few slides!

Are you ready?

Accuracy

- Why a numerical method might not give the right answer?

  - Computers have finite representation of numbers
  - Sometimes the "right answer" cannot be represented in a finite way
  - Example:

$$\pi = 3.14159265358979323846264338327950288419 71\ldots$$

Demo: Waiting for the number 1

```
from time import sleep

x = 0.0

while x != 1.0:
    x += 0.1
    print(repr(x))

    sleep(0.1)
```

What is going to happen when we run this code?

A. Code will stop after printing 11 values for x
B. Code will stop after printing 10 values for x
C. Code will not stop
D. Code will not start

Monte Carlo Methods

Texas Holdem Game: we would like to determine the probability of winning of a given starting hand

Physical experiment

vs

Numerical experiment

Numerical Experiments

- What do we want to know about a numerical experiment?
  1. What questions are we attempting to answer?
  2. What is the outcome of the experiment?
  3. Is it repeatable?
  4. Is the answer accurate?
  5. How long will it take?

Time vs accuracy trade-off

Question: Is running this method (with a certain accuracy) a good use of our time and/or computer resources?

Complexity

How long does it take to solve a problem?

Given A, B matrices of size $m \times m$, the matrix-matrix multiplication $A \cdot B$ takes τ seconds.

How long does it take to perform $C \cdot D$, matrices of size $2m \times 2m$?

```
from time import process_time
import numpy as np
from time import process_time
```

```
n = 2000
A = np.random.randn(n,n)
B = np.random.randn(n,n)

t = process_time()  # store the time
C = A @ B
t = process_time() - t
print(t)
```

```
A = np.random.randn(2*n,2*n)
B = np.random.randn(2*n,2*n)

t2 = process_time()  # store the time
C = A @ B
t2 = process_time() - t2
print(t2)
```

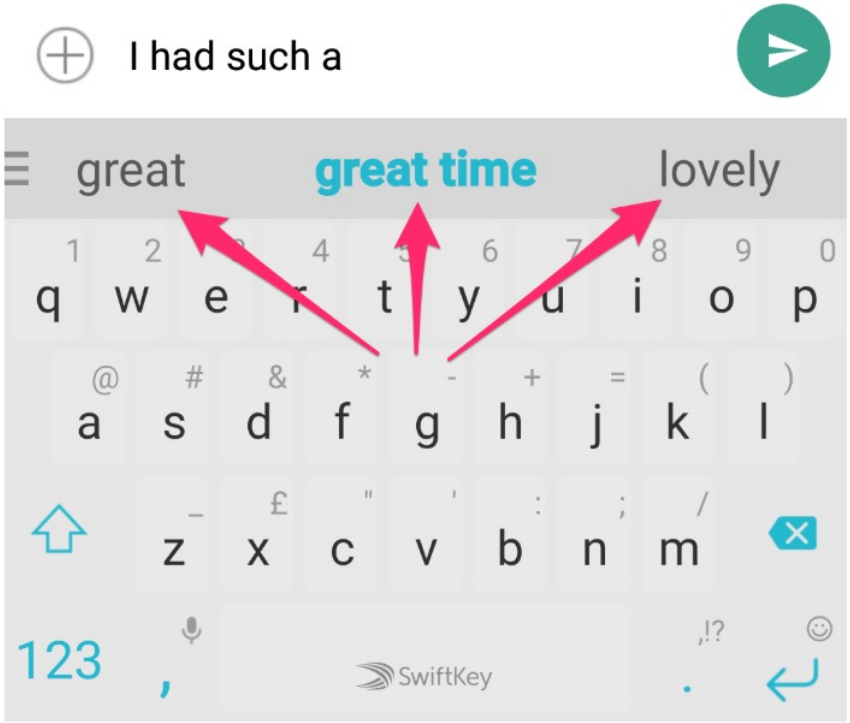
Linear system of equations: Image processing

How can we use linear operators to create blurred images? How can we do the inverse process?

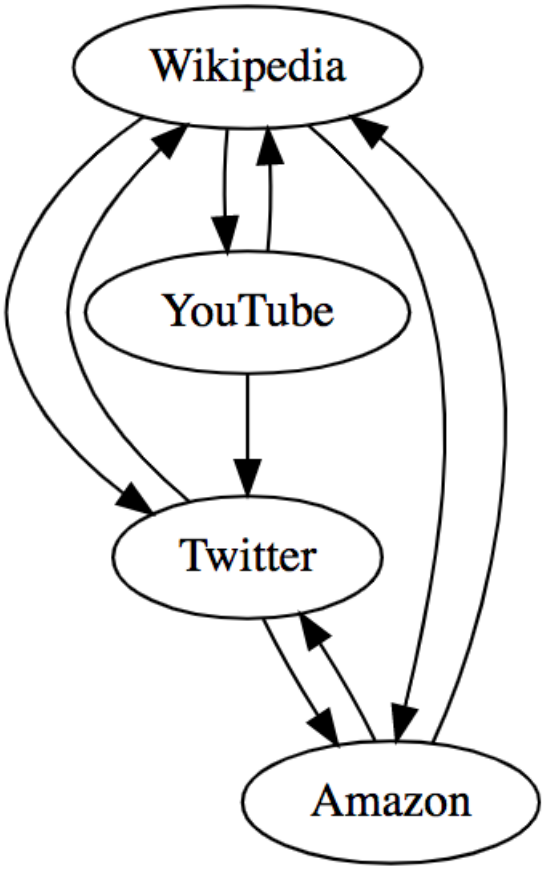
Image credit: https://datacarpentry.org/image-processing/

Markov chain

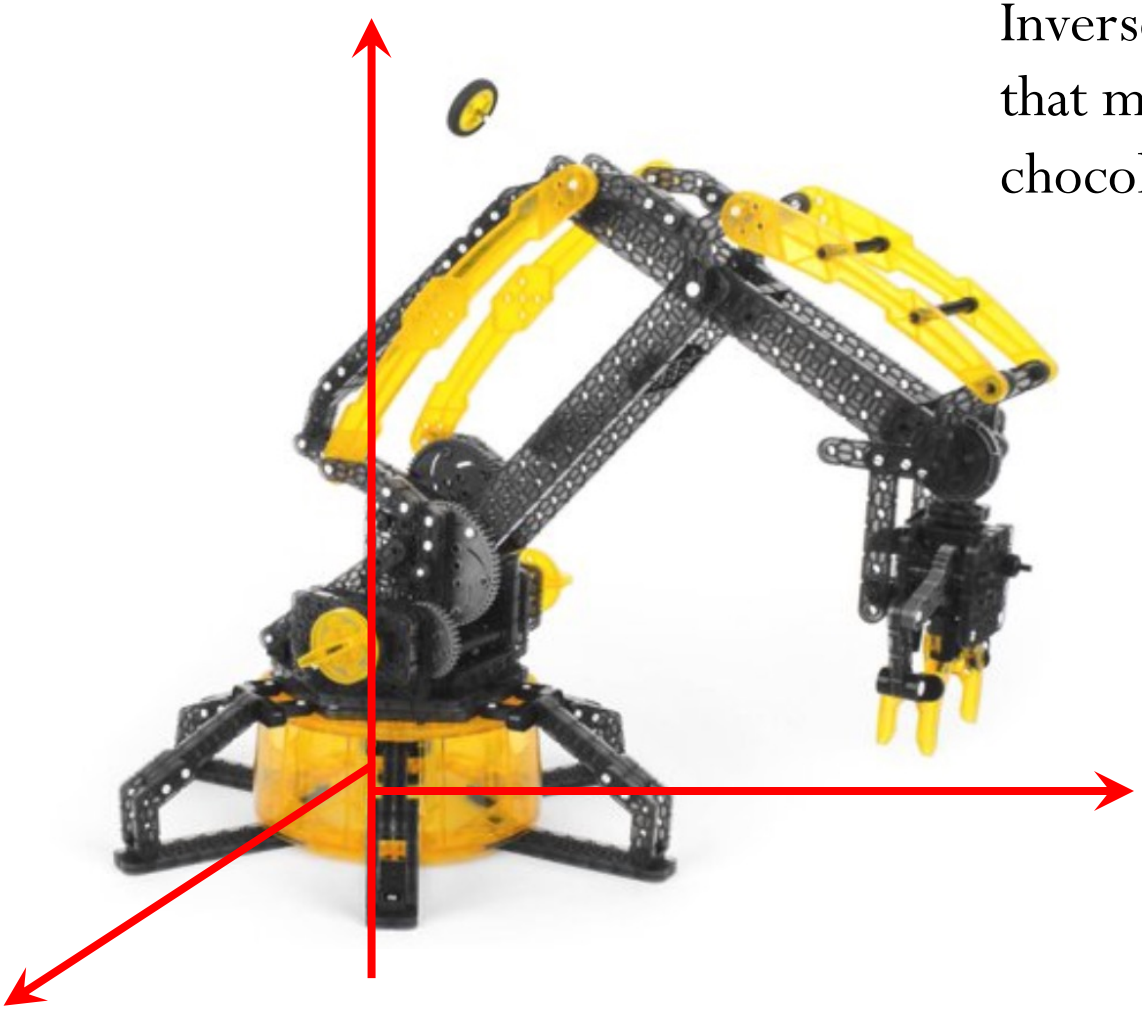
Word prediction



Page Rank



Nonlinear system of equations

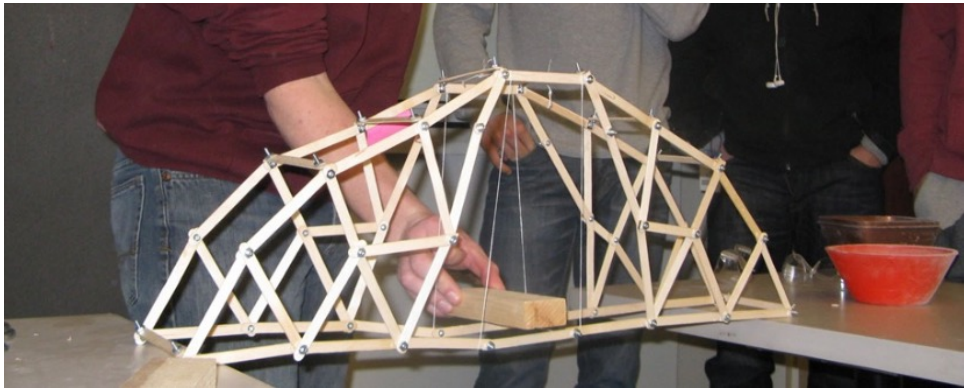


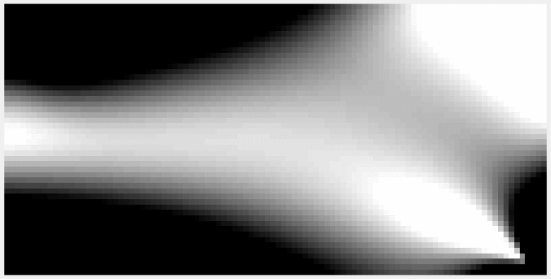
Inverse kinematics: find the angles that make the robotic hand grab a chocolate candy!

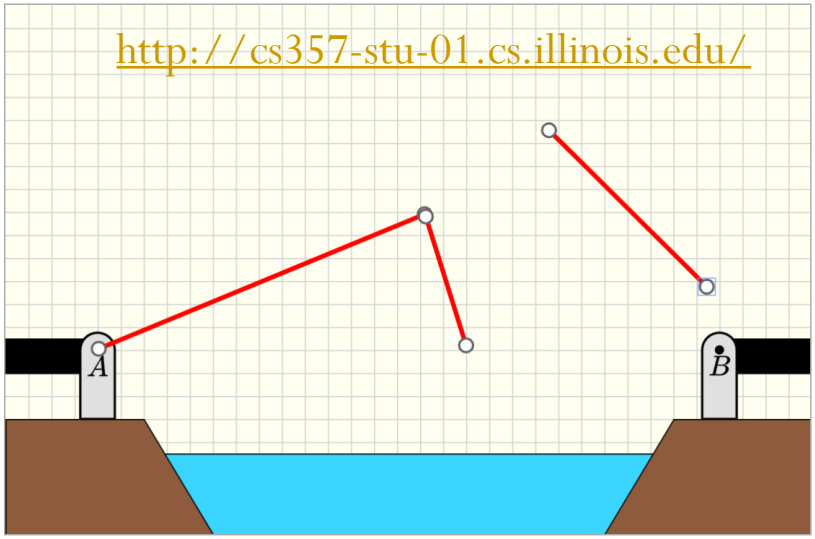
Optimization

Numerical simulations to find optimized bridge designs

Bridge design (high school projects)

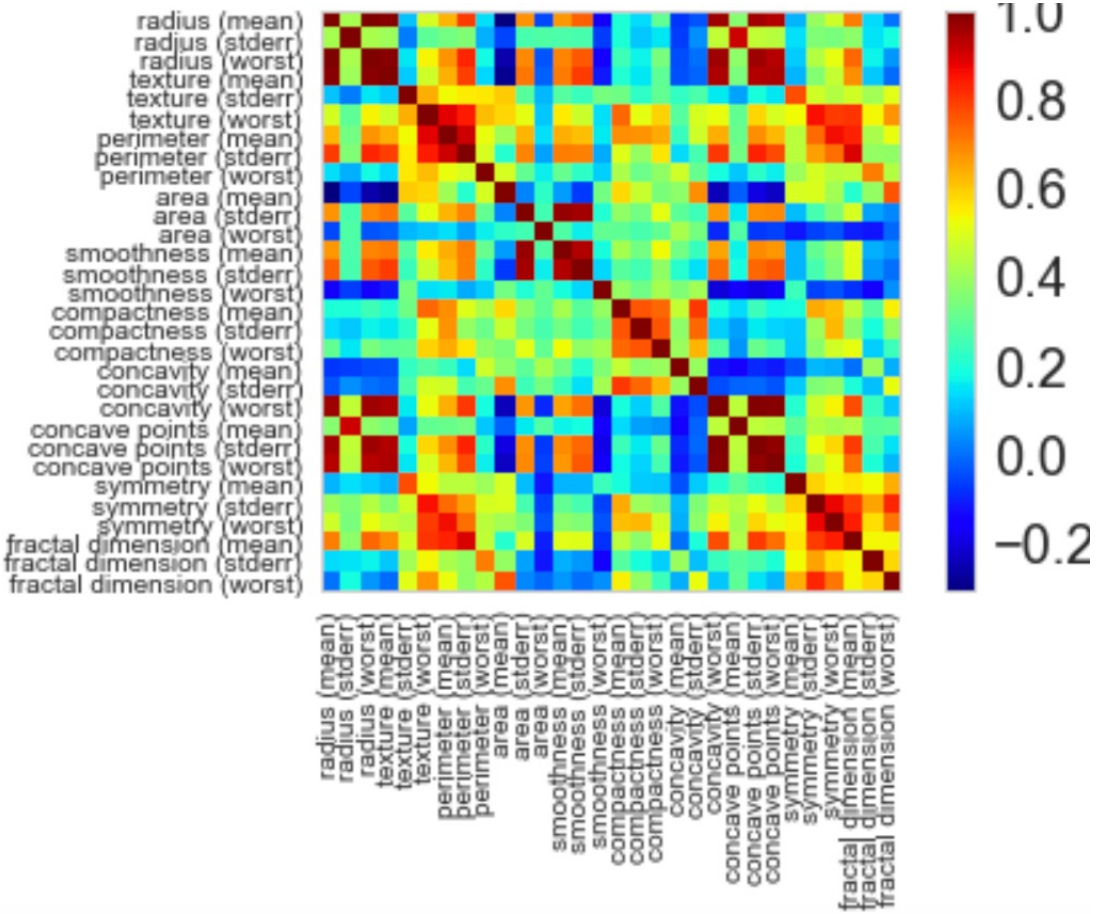


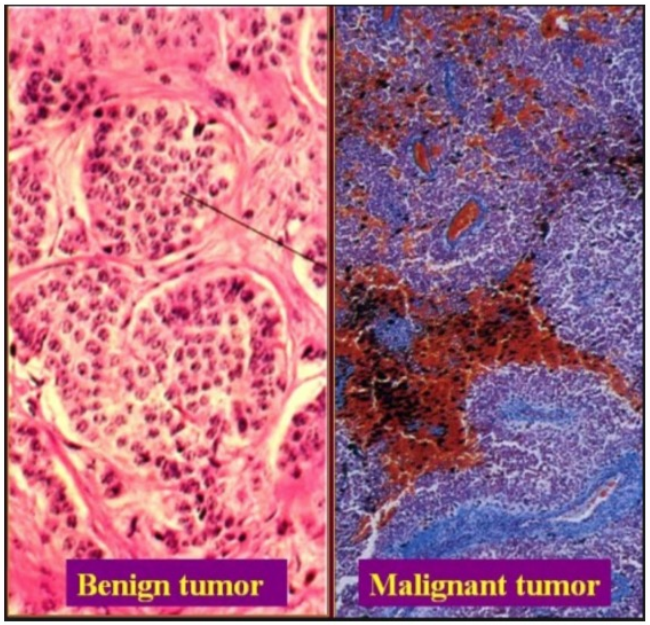




Linear Least Squares

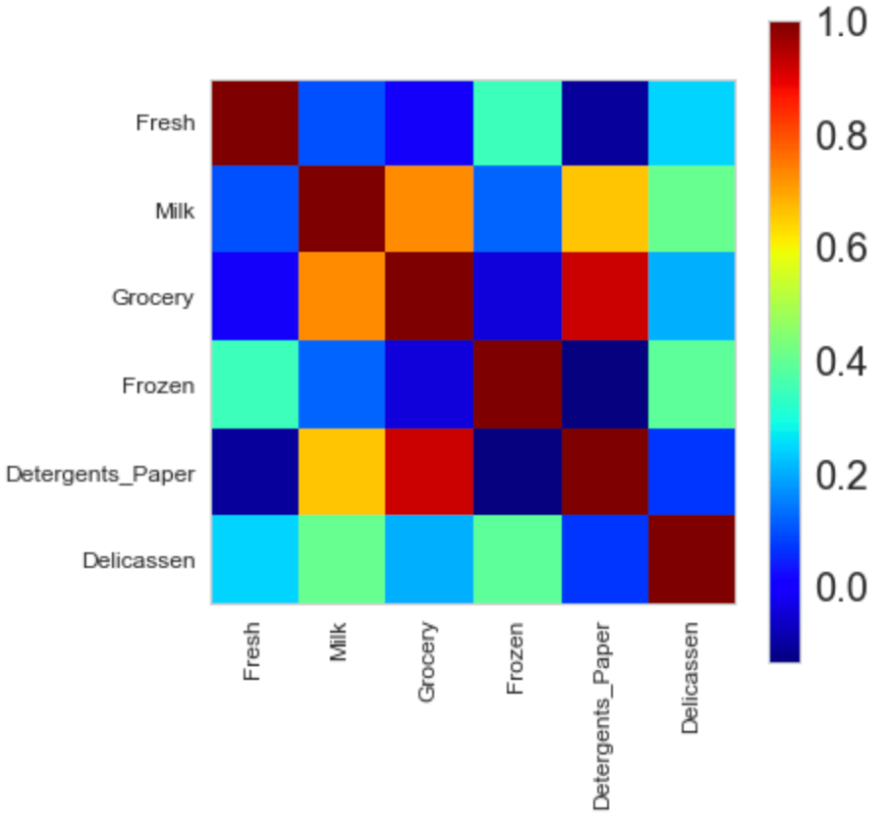
Dataset containing the characteristics of cells for several patients. Can we make predictions if cells are benign or malignant?

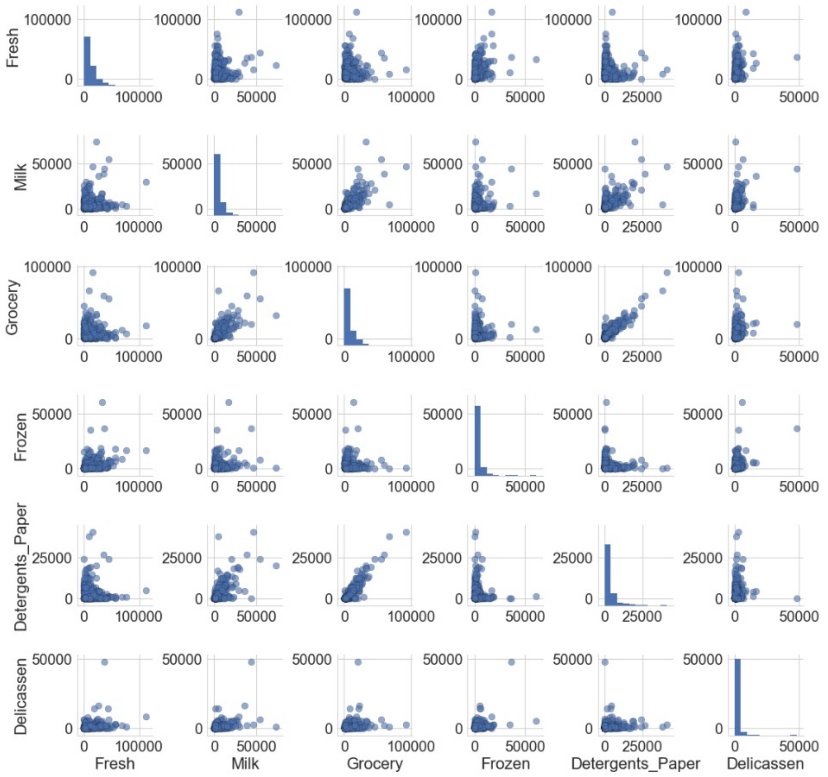




Principal component analysis

Sometimes our dataset has too many features? How can we reduce the feature space and still keep the most important information?





Second day of classes...

Assessments

Learning Flow for each Module

1. Complete lectures on Tuesdays and Thursdays as they open
    - Get up to 100% credit by completing them before Tuesday 12pm of the week after they open
    - Get up to 80% credit by completing them before Tuesday midnight of the corresponding quiz week
    - Get up to 50% credit by completing them before last day of classes
2. Complete the Homework
    - Get up to 100% credit by completing them within one week after they open
    - Get up to 96% credit by completing them before Tuesday midnight of the corresponding quiz week
    - Get up to 50% credit by completing them before last day of classes
3. Complete MPs (when available) – similar deadline scheme as HW
4. For additional examples, look at the Demos (not for credit)

Practice Quizzes

1. You are encouraged to start the practice quizzes only after you complete the learning flow above
2. Complete at least one entire practice quiz as if you were taking the quiz (no access to resources, timed, etc). This will give you a good idea of how ready you are.

Week 1

Tue, Aug 22, lecture 1
Syllabus and Course Content Overview

Complete your asynchronous lecture today!
- L1: Introduction to CS 357 (NOR FOR CREDIT)
- L2: Introduction to Python

Also opening today:
- HW1: Linear Algebra Review (NOT FOR CREDIT)
- HW2: Introduction to Python

Due today:

Thu, Aug 24, lecture 2
Intro to Python + mock group work

Complete your asynchronous lecture today
- L3: Errors, Big-O notation, plots

Also opening today:
- HW3: Errors and Big-O

Due today:

In general lectures and HWs will open at 8am Tuesdays and Thursdays.

Usually, Demos will open with the corresponding lectures (sometimes they will appear after the GA)

Week 2

Tue, Aug 29, lecture 3
GA1: Working with Python (NOT FOR CREDIT)

Complete your asynchronous lecture today!
- L4a: Floating point

Also opening today:
- HW4a: Floating point
- Q1P: Linear Algebra + Python + Errors

Due today:
- HW2: Introduction to Python

Module 2. Python

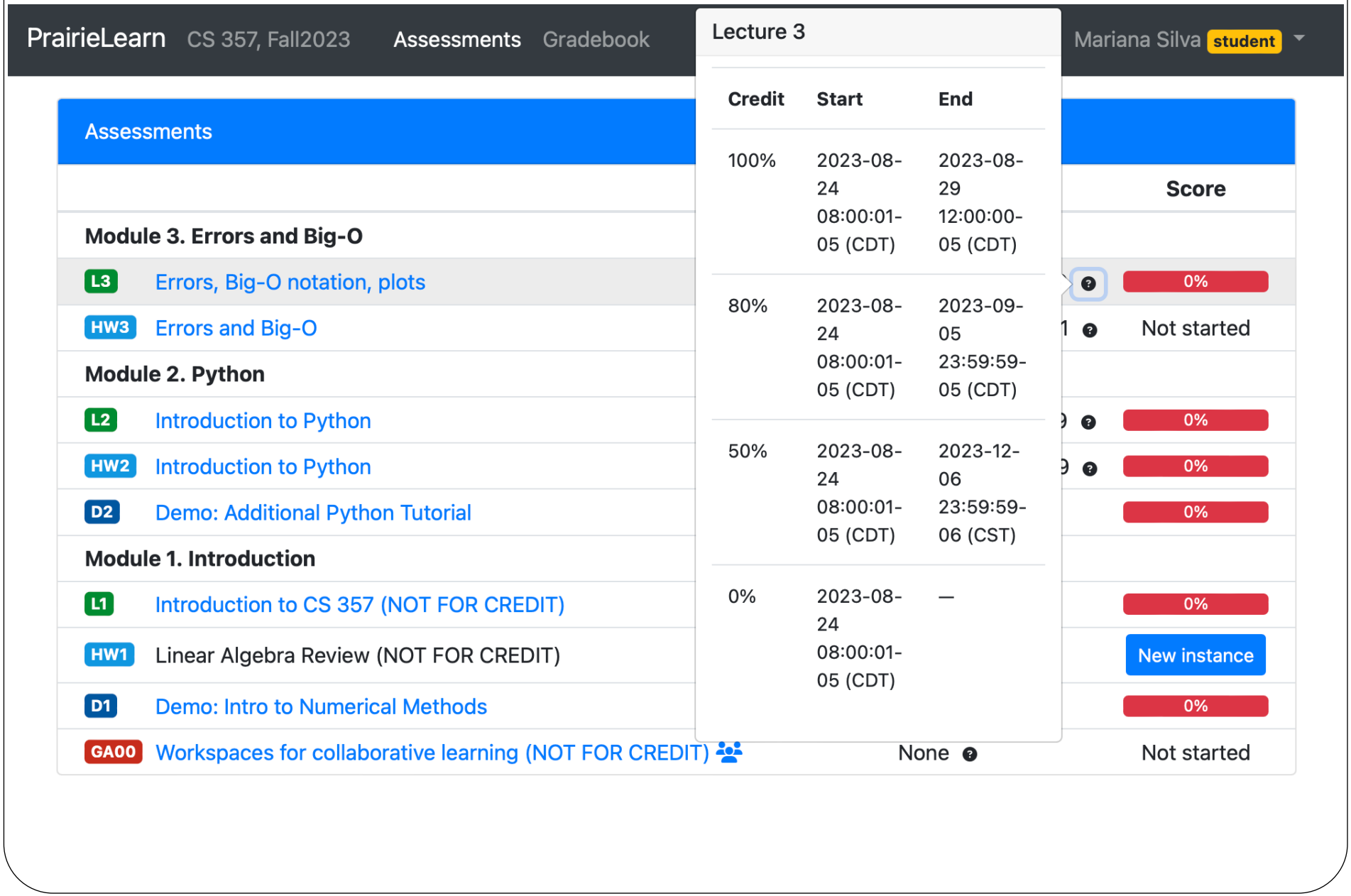
- L2 — Introduction to Python
- HW2 — Introduction to Python
- D2 — Demo: Additional Python Tutorial
- GA 1 — Working with Python (NOT FOR CREDIT)

This will be the GA next Tuesday!

Module 1. Introduction

- L1 — Introduction to CS 357 (NOT FOR CREDIT)
- HW1 — Linear Algebra Review (NOT FOR CREDIT)
- D1 — Demo: Intro to Numerical Methods
- GA 0 — Get started with GAs (NOT FOR CREDIT)
- GA00 — Workspaces for collaborative learning (NOT FOR CREDIT)

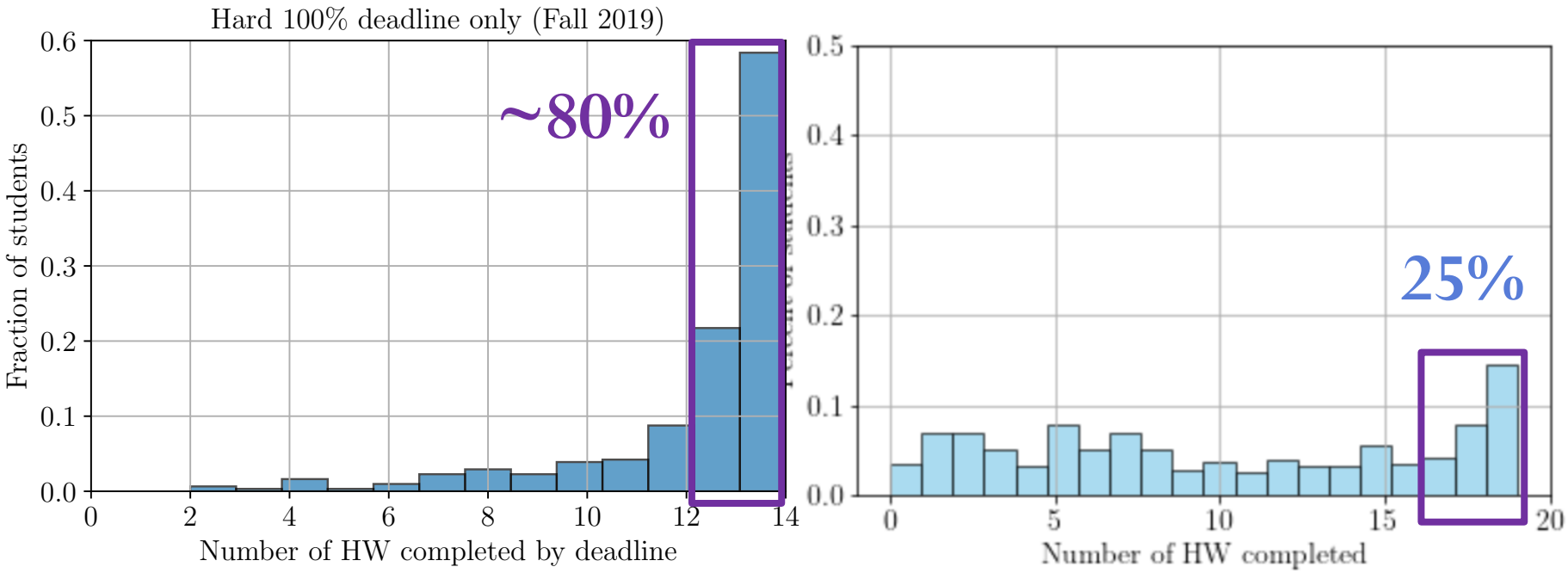
Quiz 1: Modules 1-3	
PQ1	Practice Quiz 1: Linear Algebra + Python + Errors (NOT FOR CREDIT)
Q1	Quiz 1: Linear Algebra + Python + Errors
Module 3. Errors and Big-O	
L3	Errors, Big-O notation, plots
HW3	Errors and Big-O
D3	Demo: Errors
Module 2. Python	
L2	Introduction to Python
HW2	Introduction to Python
D2	Demo: Additional Python Tutorial
GA 1	Working with Python (NOT FOR CREDIT)
Module 1. Introduction	
L1	Introduction to CS 357 (NOT FOR CREDIT)
HW1	Linear Algebra Review (NOT FOR CREDIT)
D1	Demo: Intro to Numerical Methods
GA 0	Get started with GAs (NOT FOR CREDIT)
GA00	Workspaces for collaborative learning (NOT FOR CREDIT)


PrairieLearn
CS 357, Fall2023
Assessments
Gradebook
Mariana Silva student
Assessments
Score
Module 3. Errors and Big-O
L3 Errors, Big-O notation, plots
0%
HW3 Errors and Big-O
Not started
Module 2. Python
L2 Introduction to Python
0%
HW2 Introduction to Python
0%
D2 Demo: Additional Python Tutorial
0%
Module 1. Introduction
L1 Introduction to CS 357 (NOT FOR CREDIT)
0%
HW1 Linear Algebra Review (NOT FOR CREDIT)
New instance
D1 Demo: Intro to Numerical Methods
0%
GA00 Workspaces for collaborative learning (NOT FOR CREDIT)
None
Not started
Lecture 3
Credit
Start
End
100%
2023-08-24 08:00:01-05 (CDT)
2023-08-29 12:00:00-05 (CDT)
80%
2023-08-24 08:00:01-05 (CDT)
2023-09-05 23:59:59-05 (CDT)
50%
2023-08-24 08:00:01-05 (CDT)
2023-12-06 23:59:59-06 (CST)
0%
2023-08-24 08:00:01-05 (CDT)
—

What did we learn about flexible deadlines in this class?

With "hard" one-week deadlines

With flexible deadlines

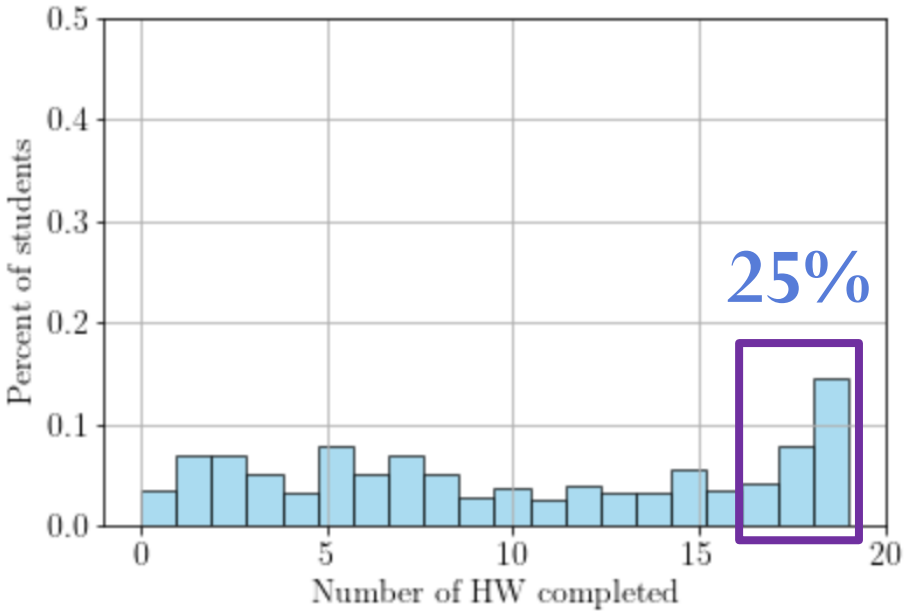


Percent of students who complete most of the HW decreased from ~80% to ~25%!

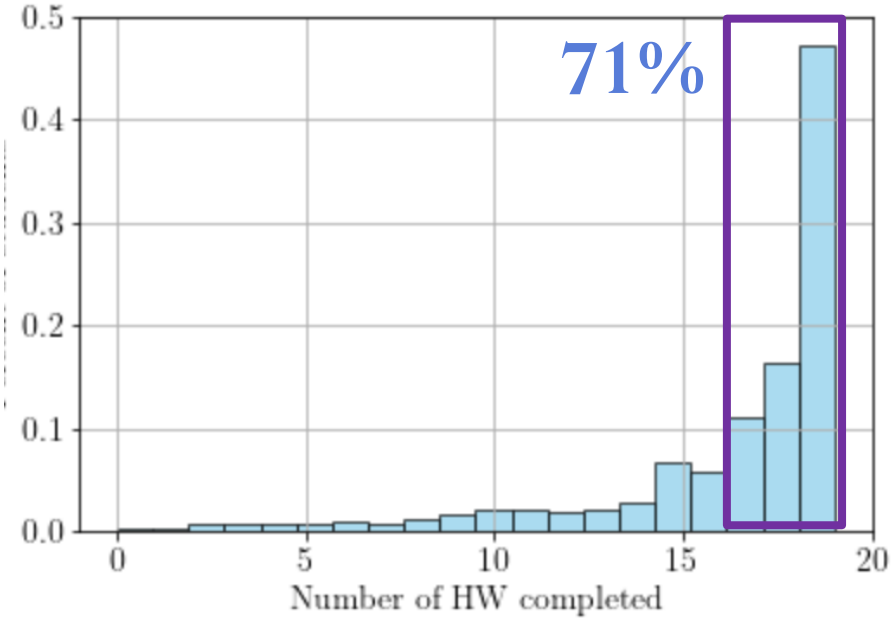
What did we learn about flexible deadlines in this class?

With flexible deadlines

Completion by 100% deadline



Completion by 96% deadline

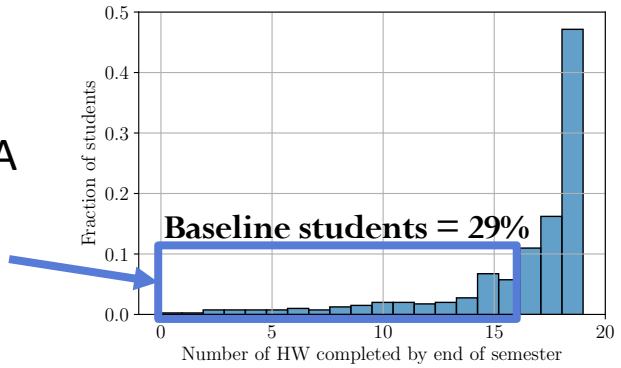


Percent of students who complete most of the HW
Increased to 71% by the quiz date

How HW completion impact quiz performance

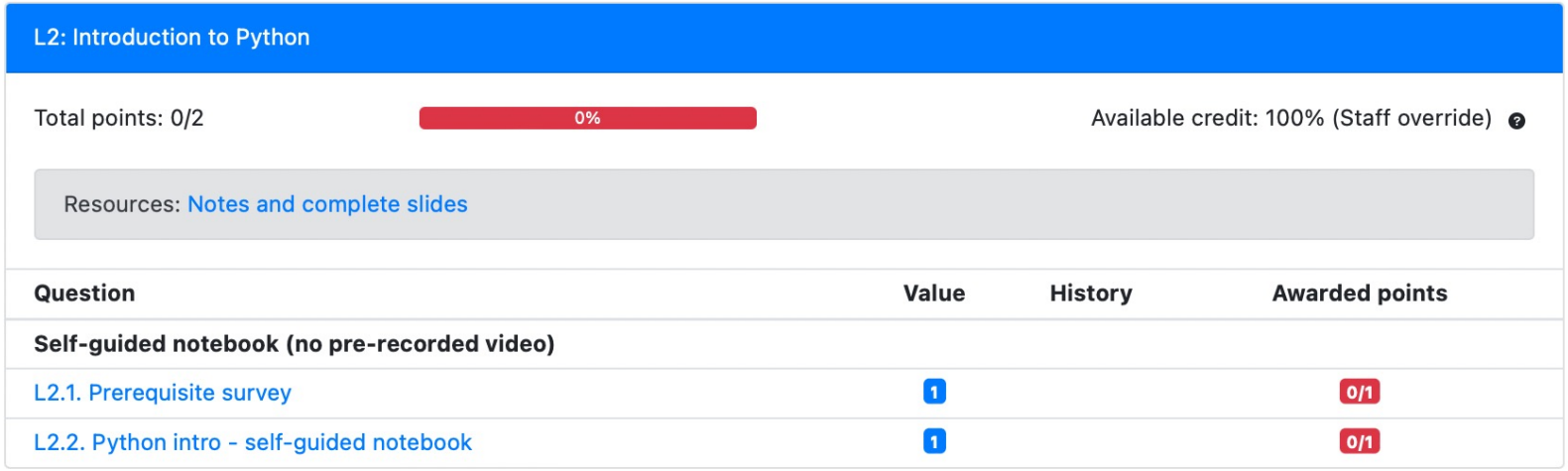
Regression model to fit exam scores including control for GPA

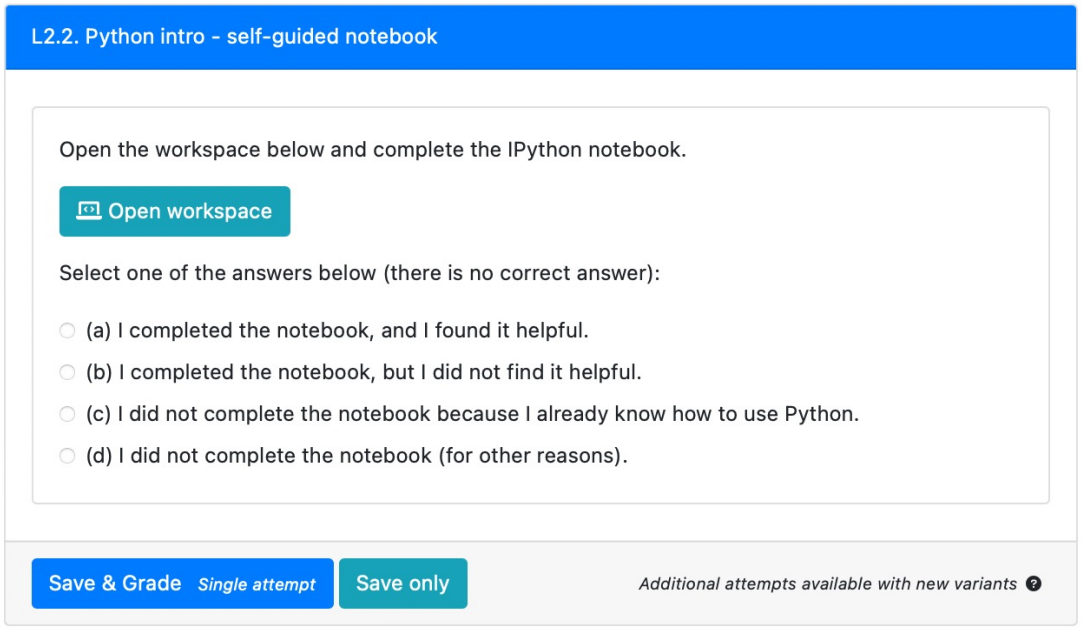
Baseline: students who did not complete HWs by the exam date



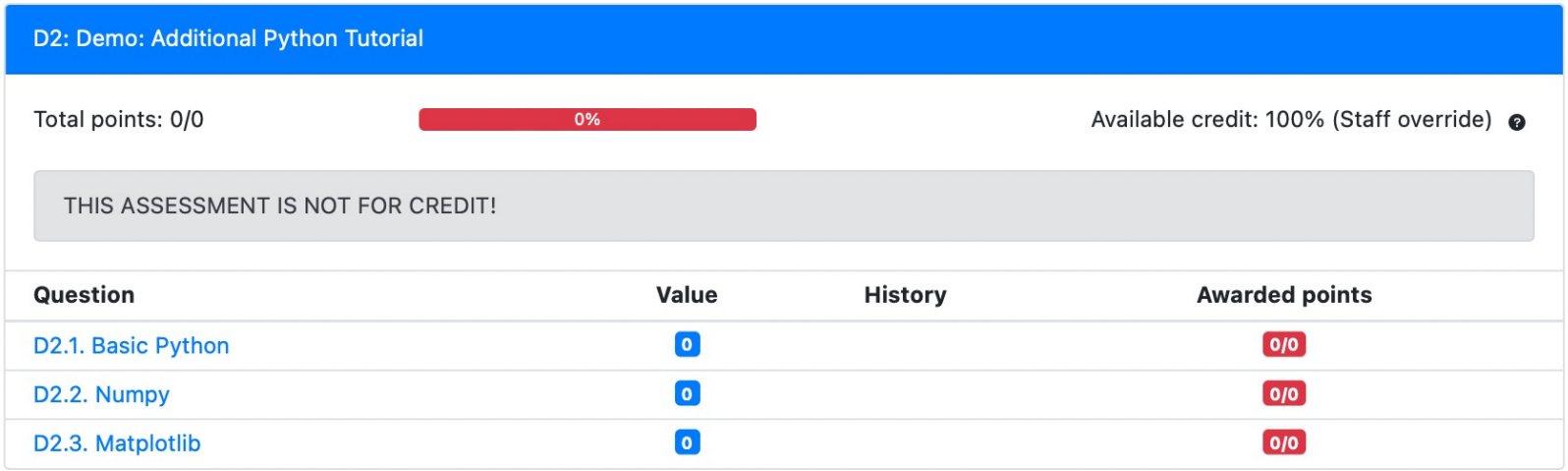
Students who complete HWs …	average score advantage on exams	% students
Do not complete	0% (baseline)	29%
by exam date	14.4%	46%
within one week	18.6%	25%

L2: Introduction to Python





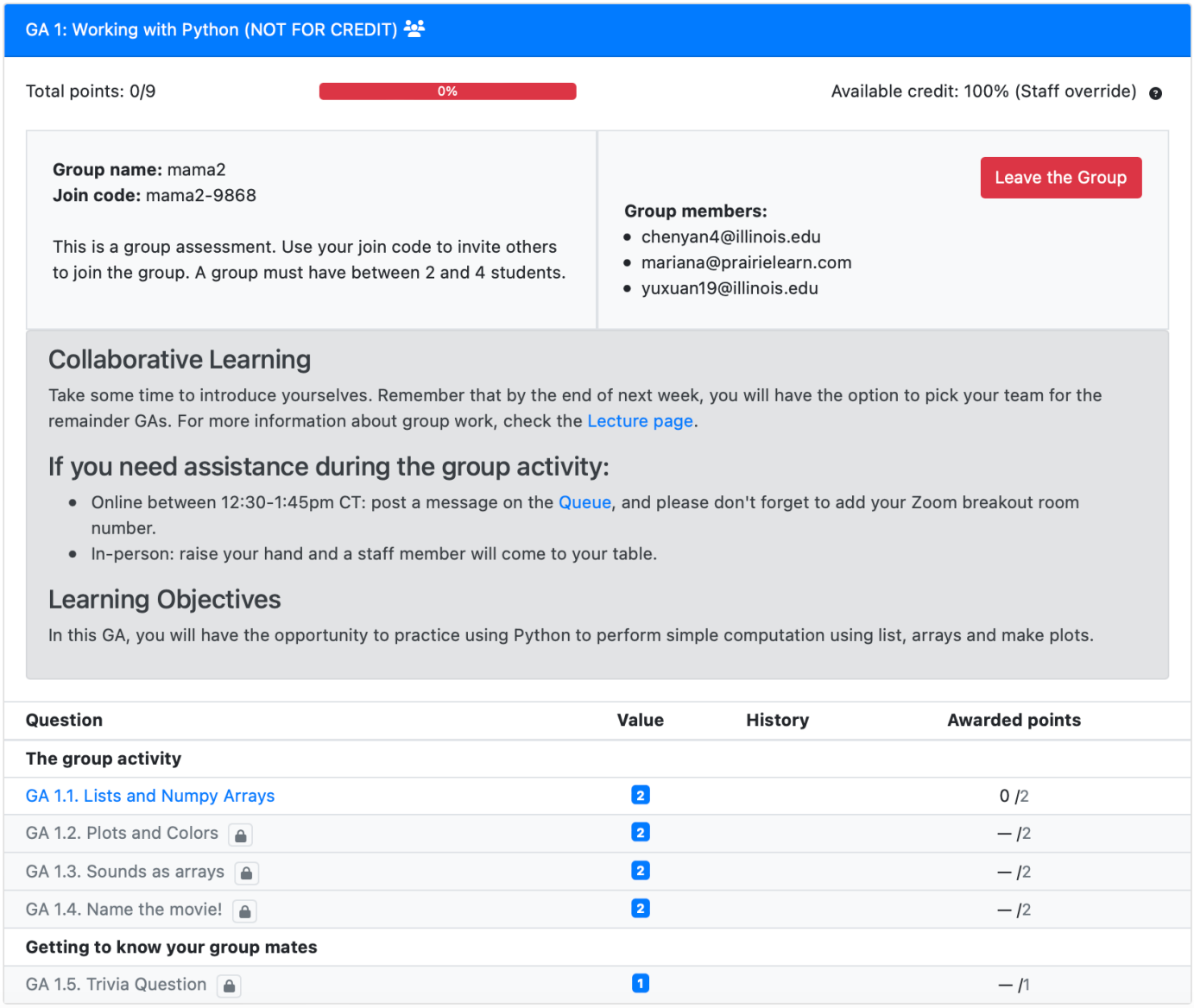
D2: Additional Python Tutorial



For the Mock GA today, you will need to:

- Define Python variables
- Define 1d numpy array
- Perform simple operations with numpy arrays

GA 1: Working with Python



GA 1: Working with Python (NOT FOR CREDIT)

Total points: 0/9 — 0%

Available credit: 100% (Staff override)

Group name: mama2
Join code: mama2-9868

This is a group assessment. Use your join code to invite others to join the group. A group must have between 2 and 4 students.

Leave the Group

Group members:
- chenyan4@illinois.edu
- mariana@prairielearn.com
- yuxuan19@illinois.edu

Collaborative Learning

Take some time to introduce yourselves. Remember that by the end of next week, you will have the option to pick your team for the remainder GAs. For more information about group work, check the Lecture page.

If you need assistance during the group activity:

- Online between 12:30-1:45pm CT: post a message on the Queue, and please don't forget to add your Zoom breakout room number.
- In-person: raise your hand and a staff member will come to your table.

Learning Objectives

In this GA, you will have the opportunity to practice using Python to perform simple computation using list, arrays and make plots.

Question	Value	History	Awarded points
The group activity			
GA 1.1. Lists and Numpy Arrays	2		0 /2
GA 1.2. Plots and Colors	2		— /2
GA 1.3. Sounds as arrays	2		— /2
GA 1.4. Name the movie!	2		— /2
Getting to know your group mates			
GA 1.5. Trivia Question	1		— /1

Collaborative Learning

- Complete weekly activity in groups
- Week 1 and 2: randomly assigned groups via Zoom
- Starting from week 3: fixed groups

Supporting Collaborative Learning with Structured roles

Manager: keep team on task

Recorder: enter most of the answers in PrairieLearn

Reflector: makes sure everyone is keeping up

Consent was given for the media usage

When structured roles were required to alternate among group member…

- more equality in the work distribution among members
- groups scored better (on average a full letter grade
- groups completed work faster (on average 2.8 hours faster)

Meeting time preference (during class or another time on Tuesday)

- no significant effects on students' exam performance, sense of belonging or satisfaction regarding the course

Team consistency

- positive effects on students' exam performance and sense of belonging, but not on satisfaction

Group selection

We will use the results of this survey to create the groups for at least the first half of the semester **(GA2-7)**. We will give students the opportunity to change groups in the second half of the semester.

If you know 2-3 other students taking CS 357 this semester, and you have agreed to complete the group activities together, you can request to be placed in the same group.

To submit this request, your group must select a group name, so that all members can submit the same answer below:

In the entry field below, enter your group's selection for the **group name**.

group name:

Important notes:

- Every student that enters the same group name will be placed in the same group.
- Make sure you agree on a creative and **unique group name**. For example, you can use the members last names combined. You don't want to be placed in the wrong group by mistake.
- **Groups must have 2-3 students**. If more than 3 students or less than 2 students submit this request using the same group name, ALL these students will be placed in groups at random!
- **Groups can only be formed with students registered in the same section.**

Students who do not submit this survey will be placed at a group at random. Students who are assigned to a random group in section N (online) must attend the Zoom meeting at 12:30pm at least during week 3 (they will be able to make other arrangements at that time).

If you change your mind, you can enter other submissions (by clicking "Save & Grade) until this survey deadline on Friday of week 2. The last submitted answer will be the one used to form the groups. Make sure you triple-check your submission with the other group members!

Save & Grade | Save only | New variant

Course surveys

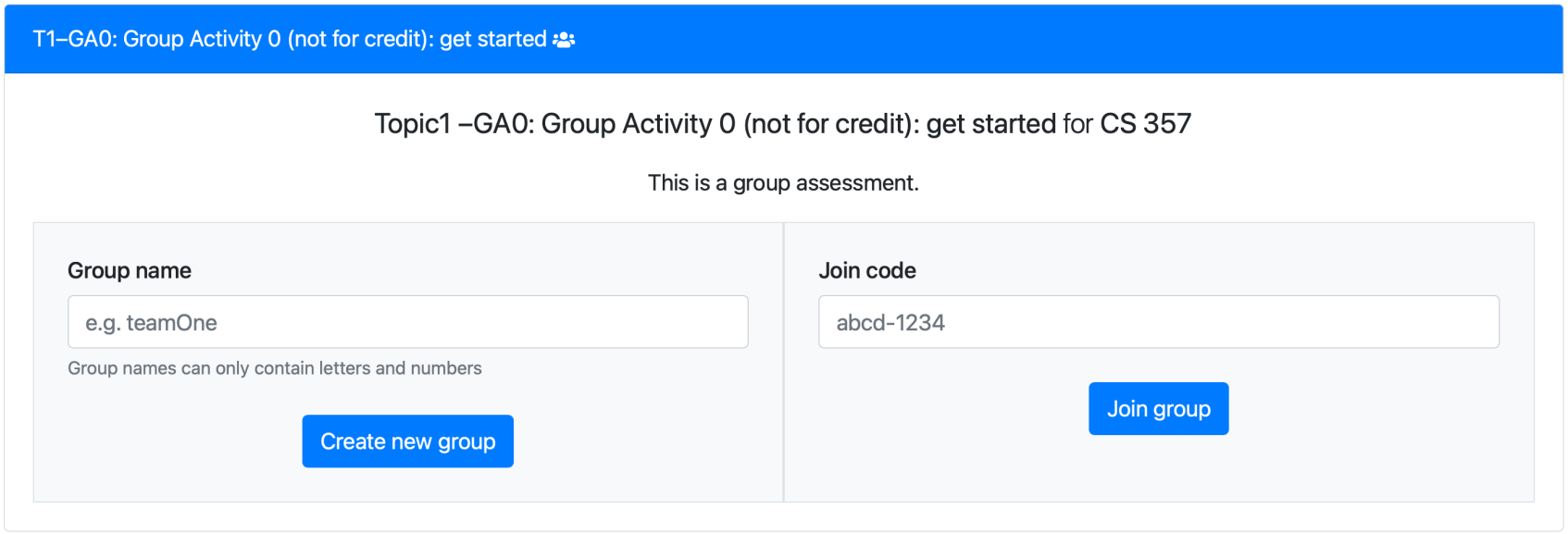
S1 Select your group (NOT FOR CREDIT)

If you are selecting a group, how did you

- (a) Knew group member(s) prior to tak
- (b) Met group member(s) during first f
- (c) Found group member(s) through c
- (d) Found group member(s) through D
- (e) Found group member(s) through o
- (f) Other

Select all possible options that apply.

Creating a group assessment in PL



Practice Group Activity